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In-House Laboratory Independent Research Program—FY88

Deborah Diemand and Mary Moritz, Editors

October 1990

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Special Report 90-34

U.S. Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

In-House Laboratory Independent Research Program—FY88

Deborah Diemand and Mary Moritz, Editors

October 1990

PREFACE

This report was compiled by Deborah Diemand, Physical Scientist, of the Applied Research Branch, Experimental Engineering Division, and Mary Moritz, Program Analyst, of the Plans and Programs Office, U. S. Army Cold Regions Research and Engineering Laboratory.

The report was technically reviewed by Peter Smallidge and Major Dale Hill of CRREL.

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In-House Laboratory Independent Research Program—FY88

DEBORAH DIEMAND AND MARY MORITZ, EDITORS

INTRODUCTION

In response to the termination of the Army's ILIR program in 1987, CRREL established an internal ILIR to continue support for high risk-high payoff basic research. This program broadly supports all of CRREL's research efforts but the major emphasis of the 1988 program is in the area of materiel development.

CRREL's goal for its ILIR program is to provide a means for innovative and high-quality research that will provide opportunities for solution of the Army's cold regions problems. The results of past ILIR projects have made important contributions to the design, construction, operation, and maintenance of northern military facilities, winter combat operations, and support of civil works activities through ice engineering and remote sensing programs. Enthusiasm for the ILIR program remains strong at CRREL and has resulted in a number of significant advances. Seventeen ILIR projects were undertaken during FY88, focusing on a wide range of basic problems relevant to cold regions research.

The 1988 CRREL ILIR resulted in a number of significant advances and opportunities for the future:

1. A new method was developed to measure shock phenomena in frozen soils with a new piezoelectric material, polyvinylidene fluoride (PVDF), which can be used as a component in a patentable shock gauge. PVDF also has great potential in laminate form for controlling stresses, by developing localized moments, and potentially has broad applications in space structures.
2. A coupled set of numerical models was developed to model ice growth in forced laminar or turbulent fluid flow in general orthogonal curvilinear coordinates. A grid generator developed for automatic generation of the model's grids includes a method that is faster, more efficient, and more accurate than standard methods. This method is of great interest to NASA and the Air Force as well as the Army.
3. A new experimental technique was produced to apply reversed (tension/compression) uniaxial loading to laboratory-grown ice samples without imparting bending moments to the specimen. This technique will have a major impact on accurately determining the mechanical properties of ice. A patent has been applied for.
4. Passive microwave and SAR imagery were obtained of ice-covered waterways in Alaska. These were compared with ground truth observations and measurements. The results suggest that both types of imagery will be useful in locating groundwater discharge zones, and pools and channels under the ice, important capabilities for Army winter operations.
5. A concept for a new probe has been developed and confirmed for automatically measuring parameters necessary to predict icing conditions at remote sites. Existing methods either yield inadequate information or are labor intensive.

6. A computer method was developed for computation of layered system responses to incident plane waves. The method succeeded in increasing layer resolution with short pulse radar by about an order of magnitude. This resulted in a state-of-the-art method for predicting and detecting phase signatures for thin ice layers.
7. A continuing ILIR concerning river ice breakup developed a predictive model which was applied to the Connecticut River in the spring of 1989.
8. Several projects dealt with modeling or measuring the mechanical properties of ice including ice friction, shear strength, and deformational processes; others considered hydraulic conductivity in frozen soils.

These projects, and several others not mentioned here, reflect the interest in the ILIR program by the CRREL research staff and the excellent results achieved. The basic studies in CRREL's ILIR program will benefit future Army programs, especially in combat engineering and logistics support.

Current and historical data on CRREL ILIR Program

	FY88	FY87	FY86	FY85
Funds received (K$)	*	267	400	400
Funds obligated (K$)	310	265	400	400
Manpower (MY)	4.9	5	7.8	8.9
Number of tasks	17	12	6 *	6**
Average task size (K$/MY)	18.2/0.3	22.2/0.5	67/1.3	67/1.5
Number of continuing tasks	10	2	3	3

* Army's ILIR program terminated in 1987. Funding for CRREL's ILIR 88 program is drawn from internal sources.

** These reports grouped individual projects into six separate categories.

FY88 ILIR EFFORTS

The following pages present the FY88 In-House Laboratory Independent Research work units ranked in the order of their success.

TITLE

Determining Shock Attenuation in Frozen Soil by Hopkinson Bar (485)

INVESTIGATOR

P. K. Dutta

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	18	0.33	0

OBJECTIVES

The objective of this project was to study the shock wave attenuation in frozen soil by developing a novel polymeric piezoelectric shock gauge. For hardening of military structures built on frozen soil, evaluation of responses in the region close to weapon explosions—including high yield events (nuclear) and low yield events (conventional explosives)—is essential. The results of this project will help to develop understanding of these responses.

APPROACH

A new method to determine shock wave response and attenuation in frozen soil using the computerized CRREL Hopkinson Bar was investigated. A theoretical basis for shock Hugoniot response of frozen soil from the Hopkinson Bar data was proposed and new equipment for producing air-bubble-free frozen soil cylindrical specimens was designed and developed. As one of the major thrusts of this project, a new piezoelectric material, polyvinylidene fluoride (PVDF), was thoroughly investigated to evaluate it as a shock gauge, and a technique for using it as a shock sensor and associated electronic instrumentation was developed.

ACCOMPLISHMENTS

The results provided two potential payoffs. First, the piezo-polymer sensor developed can be further improved to be transformed into a patentable product. Also, when embedded in a laminate, it has the potential for controlling stresses by developing localized moments, and thus can be a excellent vibration attenuator in many applications including space structures.

Baseline data of shock wave attenuation for only one type of soil were generated. Tests on more types of soil with variation of moisture percentage and grain size are necessary and can be done by using this newly developed test method.

TITLE

Ice Growth in Forced Flow (489)

INVESTIGATOR

M. R. Albert

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	20	0.33	0

OBJECTIVES

The objective of this research was to develop a coupled set of numerical models to model ice growth in the presence of forced laminar or turbulent fluid flow. No such models existed in the literature prior to this research.

APPROACH

A finite volume procedure was selected and implemented that models fluid flow in general orthogonal curvilinear coordinates. The coupled set of models consists of FLUID, a model that solves the Navier-Stokes equations and associated energy equations in the fluid flow field, and ICE, a model that solves the heat conduction equation to determine the temperature field in the ice. The two solutions are linked by the latent heat condition at the moving ice–water interface to form TWOPHASE, the coupled model that analyzes the moving boundary problem of ice growth in the presence of fluid flow. In addition, a grid generator for general orthogonal coordinates was developed to automatically generate the grids necessary for the model. It was also necessary to develop post-processors (graphing programs) in order to visualize and interpret results.

ACCOMPLISHMENTS

The model developed can handle arbitrary geometries, making it applicable to a wide variety of ice problems of interest to the Army and others. The application of the model to the wavy ice problem will lead to an explanation of the basic phenomenon and a definition of conditions under which it is expected to occur, and will also yield applied results such as prediction of head losses in pipes when wavy ice is present.

In the process of developing the grid generator for this model, I discovered a method that is faster, more efficient, and more accurate than the standard methods. The contribution to the field of grid generation is of great interest to NASA and the Air Force, and will also facilitate research being done for the Army.

It is hoped that publications resulting from this work will further demonstrate that CRREL has extensive capability in the field of computational fluid dynamics, and that a reimbursable program can be developed that involves this capability.

TITLE

Cyclic Loading of Ice (486)

INVESTIGATOR

D. M. Cole

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	16	0.35	0

OBJECTIVES

This work was intended to produce an experimental technique to apply reversed (tension/compression) uniaxial loading to laboratory-grown ice specimens in a manner that imparts no bending moments to the test piece. Development of such a capability 1) opens up a new and important area of mechanical properties testing and 2) provides a more sophisticated means to perform traditional uniaxial experiments on ice.

APPROACH

A device was built and tested and 10 experiments were performed. The device met or exceeded our expectations in all respects and the brief series of experiments clearly demonstrated its operational capabilities. A patent application for this device was submitted since we believe that it possesses several unique features not found in existing devices that perform similar functions.

ACCOMPLISHMENTS

The development of this device is a significant advance to the state of the art in laboratory testing for the mechanical properties of ice and will keep CRREL in the forefront of this field. We will now be able to conduct a variety of experiments that have heretofore been impossible and that will give valuable insight to certain aspects of ice behavior. In addition, it is now possible to pursue outside funding sources to continue this work.

A conference paper giving an account of this work was presented at the 1989 Offshore Mechanics and Arctic Engineering Symposium.

TITLE

Development of a Predictive River Ice Breakup Capability (495)

INVESTIGATOR

M. G. Ferrick

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	20	0.45	0

OBJECTIVES

The objective was to develop a predictive model of river ice breakup.

APPROACH

A series of controlled ice breakup simulations were performed for various ice thickness and ice strength conditions that indicated large differences in the results. These results bracket the expected river response to a controlled breakup water pulse. The lack of field data obtained during an ice breakup is currently the limitation on applications of this research. Field data sets from either the Connecticut or St. John (New Brunswick) rivers will be pursued under separate funding for verification of the model.

ACCOMPLISHMENTS

The model developed in this program was applied to the Connecticut River and will be applied to the St. John River.

A paper describing this research was presented at the *Fourth International Symposium on Regulated Streams*. The written version of this paper entitled "Framework for Control of Dynamic Ice Breakup by River Regulation" was accepted for publication in the *Journal of Regulated Rivers*. Also, a CRREL report entitled "Framework for Control of Dynamic Ice Breakup by River Regulation" was published. These papers document the latest version of the model and its theoretical basis.

TITLE

Interpretation of River and Lake Ice from Airborne KRMS and SAR Imagery (499 and 500)

INVESTIGATOR

L. W. Gatto, R. A. Melloh and E. F. Chacho

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	0	0.5	10

OBJECTIVES

This project took advantage of a first time opportunity to acquire passive microwave and SAR images concurrently with field data. The objectives were to expand existing knowledge regarding passive and active microwave imagery patterns as produced by different river and lake ice conditions, and to provide interpretive keys for analyzing such patterns on existing microwave images.

APPROACH

We acquired K_a-band Radiometric Mapping System (KRMS) 33.6-GHz passive microwave and multiband synthetic aperture radar (SAR) images of the Tanana River and Harding Lake. Ground-truth observations and measurements were made within three days of imagery acquisition. A video tape was made of the river and lakes to be used in interpreting ice conditions. KRMS images were field checked. Cross-section and core sample drawings were used to assess the correlation between image patterns and snow and ice surface, internal and subsurface conditions. Detailed comparisons of the field data and KRMS and SAR images will be done during the rest of the project.

ACCOMPLISHMENTS

The results show that both types of imagery will be useful in evaluating freshwater ice conditions and suggest that this type of imagery may be useful in locating groundwater discharge zones, pools and channels under ice for CRREL's Winter Water Supply Program and in surveillance of river ice for military bridging operations.

A report on the work with Harding Lake KRMS images was reviewed and is being revised. SAR images of the Tanana-Chena rivers confluence were received from JPL. Preliminary evaluations suggest that differences in ice conditions were detected by the radar and analysis will be possible.

TITLE

Design of a Continuous Automatic Probe for Liquid Water Content and Droplet Size during Icing Storms (497)

INVESTIGATOR

K. F. Jones and S. F. Ackley

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	10	0.2	0

OBJECTIVES

The modeling of ice accretions on structures such as towers, transmission lines, and aircraft has shown that two essential parameters for predicting the amount of ice that accretes are the liquid water content L_W and the droplet diameter d. Existing commercial automatic ice detectors give a qualitative indication of the severity of the icing storm but cannot measure L_W and d. On the other hand, the multicylinder method currently used at the Mount Washington Observatory and icing research facilities in Norway and Finland does determine L_W and d but is labor intensive. The objective of this project was to investigate the feasibility of an automatic two-cylinder probe to determine L_W and d from the mass of ice accumulated on each cylinder during a known time period.

APPROACH

The accuracy of a two-cylinder probe was evaluated by using data from the Mount Washington Observatory multicylinder. Two of the cylinders on the multicylinder were used as a pseudo-two-cylinder probe, and the predicted d and L_W were compared with those determined by the multicylinder analysis. This comparison was done for five pairs of cylinders to determine the optimum cylinder sizes. The pair of cylinders that gave the best agreement with the multicylinder values were 0.50 and 2.54 cm in diameter.

ACCOMPLISHMENTS

This analysis defined the hardware and software requirements for an automatic two-cylinder icing probe. Such a probe, used in conjunction with windspeed and temperature gages would give fundamental meteorological information for remote sites and allow the Army to predict the severity of site-specific icing on a structure.

TITLE

Prediction and Analysis of Radar Backscattering (491)

INVESTIGATOR

K. O'Neill

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	22	0.3	0

OBJECTIVES

This research addressed a need to interpret radar returns from buried objects, including the effects of ambient terrain. It was divided into two parts in which computer methods were developed for determining 1) the radar response of an arbitrarily shaped highly reflective object, without reference to the complications provided by the surrounding medium, and 2) the radar response of a layered system in which a dielectrically inhomogeneous surface layer exists below the normal level of resolution (but the layer is thick enough to blur the return). These were seen as first steps in a development that would ultimately combine both problems.

APPROACH

Part 1: A computer formulation of the electromagnetic system was produced incorporating innovations at three stages of the computation:

a. *Problem setup stage.* Software was produced capable of reducing the surfaces of arbitrarily shaped objects to a mesh of small elements.
b. *Assembly and solution stage.* Calculations were streamlined using a preprocessing method and a new program was developed for elimination/solution of equations.
c. *Final stage.* Innovations were developed in the calculation of the backscattered field.

Part 2: A computer method was developed for computation of layered system responses to incident plane waves. Both methods developed succeeded in increasing layer resolution with short pulse radar by about an order of magnitude.

ACCOMPLISHMENTS

Innovations in part 1 allow direct computation of the reflected power and other details from analytical expressions for gradients of field quantities, a more reliable method than that commonly used.

Part 2, the most successful of the two, resulted in a state-of-the-art method for predicting and detecting phase signatures for thin ice layers.

This work is relevant to Army requirements in its contribution to mine-countermine operations, terrain classification and mapping, and mobility determinations. This last item is important because the systems developed should help determine depth of thaw and surface layer water content by remote sensing. This research also contributes in a fundamental way to our knowledge of effects of environment on remote sensing signals. Thus it is important as an aid to automatic target recognition system design and testing.

TITLE

Scanning Electron Microscope Applications to Ice and Frozen Soil (487)

INVESTIGATOR

D. M. Cole and S. Taylor

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	12	0.3	0

OBJECTIVES

The objective of this work was to develop experimental techniques for the etching and replication of pure ice and of ice containing fine particles. Such techniques allow us to investigate grain boundary structures and the linear defect (dislocation) population in ice. This information in turn gives us valuable insight regarding the mechanisms underlying the mechanical behavior of the material.

APPROACH

The approach is primarily experimental. The development of the etching and replication technique will allow us to examine the microstructural characteristics of frozen soil after deformation to various levels of creep strain. Evidence of changes in both the soil particle arrangement and the pore ice characteristics will be sought in an effort to monitor the processes that lead to the onset of tertiary creep.

ACCOMPLISHMENTS

The critical aspects of the etching and replication process were developed: micrographs were obtained for pure ice, ice containing various-sized synthetic spheres, and a frozen clay slurry. This work both answered a number of immediate questions and initiated an experimental capability that will be of great use in a variety of projects at CRREL. The micrographs give clear indications of the structure of the grain boundaries in bulk ice and in pore ice. Interestingly, significant irregularities along with features known as grain boundary ledges were observed. These observations are significant in that they appear to support the contention that grain boundaries can act as sources of dislocations in ice.

Although some additional considerations must be addressed regarding thin sectioning methodology in soils, the products of this project impact directly on efforts to develop a mechanistic understanding of deformational processes in ice and ice-rich materials. The need for microstructural information on frozen soil, in particular, is necessary to address the shortcomings in our current level of understanding of this material.

TITLE

Physical Changes Induced in Dry Snow as a Result of Kinetic Growth Metamorphism (488)

INVESTIGATOR

M. Sturm, E. F. Chacho and J. B. Johnson

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	25	0.3	0

OBJECTIVES

Kinetic metamorphism of dry snow produces substantial layers of depth hoar in the seasonal snow covers of Alaska, Canada, Northern Europe and Russia. Our objective was to make detailed measurements of the physical properties of depth hoar in Alaska and to understand the relationship between the physical properties of the depth hoar and dry snow metamorphism.

APPROACH

We observed depth hoar and wind slab snow covers on a 500-km transect extending from Fairbanks to the arctic coast. We measured dielectric constant, density, and temperature profiles as well as micro-topography of the snow. The transect was part of a cooperative effort between CRREL, JPL and NASA in which the new synthetic aperture radar (SAR) belonging to NASA was tested over snow and sea ice.

We investigated the relationship of the thermal conductivity of the snow to the snow texture and temperature. The results suggest that the thermal conductivity can vary by a factor of two over normally occurring winter temperatures.

In addition, we analyzed data indicating that convection is prevalent in the depth hoar snow cover.

ACCOMPLISHMENTS

This work documents the fundamental properties of the snow that affect rates of soil and ice freezing, trafficability and the movement of contaminants through the snow. Two types of convection were identified. The results have produced several papers and presentations at national meetings and have contributed to a doctoral dissertation. Our plan is to extend our snow research to other types of snow covers in addition to depth hoar.

TITLE

Fiber Optic Determination of Moisture/Water Content (501)

INVESTIGATOR

K. V. Knuth and R. L. Berg

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	25	0.26	0

OBJECTIVES

Recently it has been shown that fiber optics can be used in sensors for a variety of phenomena, including moisture. The objective of this project was to build and test two such probes, one a humidity sensor and the other a soil moisture sensor.

APPROACH

After designing and building the electronics and optical interface for the humidity sensor, testing showed that the plastic fiber optic cable that was selected had a major problem with its connectors and also a large internal attenuation. It was found that a similar and improved sensor had been developed at Rutgers, so work was suspended pending testing and evaluation of the Rutgers design.

A soil moisture sensor was constructed using silicon fiber optic cable. This probe was tested in silt with moisture contents of 0 to 40%. All tests showed a proportional response to moisture content but the responses varied greatly from test to test. This may be due either to perturbation of the soil between measurements or to water absorption by the plastic cladding on the cable.

ACCOMPLISHMENTS

Through this project CRREL has gained much experience and knowledge of fiber optics and fiber optic sensors along with the needed equipment required to make fiber optic measurements.

The soil moisture sensor was shown to be feasible and the Rutgers humidity sensor shows promise for future development.

TITLE

Nondestructive Determination of Transport Coefficients in Frozen Soils by the Dual-Energy Gamma-Ray Device (498)

INVESTIGATOR

O. A. Ayorinde, R. L. Berg and D. E. Pidgeon

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	20	0.5	0

OBJECTIVES

Current techniques for determining hydraulic conductivity and other soil properties that greatly influence the transport mechanism in soils during freezing are done destructively. As a result, available data on transport coefficients vary widely. By using the dual-energy gamma-ray (DEGR) device, freezing-induced moisture or chemical movement and soil density variations can be monitored and measured from location to location without disturbing the soil sample. The technique provides accurate data for moisture profiles and transients that yield reliable data needed for accurate evaluation of transport coefficients. These data are then used to determine soil-specific transport coefficients that are essential for 1) modeling frost heave, 2) studying the behavior of chemical/nuclear/moisture transport in frozen soils applicable to nuclear attack situations, and 3) cost-effective design of foundations in cold regions that are of interest to the Army.

APPROACH

The DEGR technique uses two radioactive sources for simultaneous measurement of soil density and moisture content. Moisture movement and soil density variations can be monitored and measured during freezing from location to location without disturbing the soil sample. Different soil types will be subjected to varying freezing conditions to determine soil-specific transport coefficients.

ACCOMPLISHMENTS

Due to the unexpectedly long delay in obtaining the required license from the U.S. Nuclear Regulatory Commission to operate the DEGR device, testing could not be begun in 1988. However, the test procedures for the operation and calibration of the device test apparatus were completed. Also, the analytic procedure required to analyze the ensuing DEGR data was developed and proof-tested. In addition, the DEGR device mechanical/structural components and the nuclear instrumentation module's (NIM) electronic data acquisition components were thoroughly calibrated and proof-tested. The results of these preliminary testing procedures showed that the DEGR device performed as designed. Such information provides the background needed to use the DEGR device to determine transport coefficients in frozen soils.

TITLE

Development of a Device to Measure the Shear Strength Characteristics of Frazil Ice (492)

INVESTIGATOR

J. H. Rand and E. P. Foltyn

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	24	0.3	0

OBJECTIVES

One frazil ice control technique that has shown promise is the use of a permeable material, such as chain link fence fabric, which captures active frazil ice, gradually clogging the fabric and thus reducing the flow of water. This results in the formation of an ice cover upstream and prevents further frazil formation. As the upstream head increases, this accreted ice can fail. Thus, to optimize the design and location of frazil screens, knowledge of the "structural integrity" of frazil ice was necessary. Accordingly, the objective of this work was to develop a device to measure the shear strengths of frazil ice accumulations.

APPROACH

A simple-shear box suitable for use with the soft, weak material in question was built and instrumented. The instrumentation consisted of three load cells to measure the normal load, and a load cell and a linear velocity displacement transducer to measure the shear load and shear displacement rate. Pneumatic air cylinders were used to apply the normal and shear loads.

ACCOMPLISHMENTS

The apparatus was fabricated and the instrumentation installed, but only limited testing was conducted to verify that the system works as anticipated. Time limitations imposed during procurement of the instrumentation precluded further progress. However, a test plan was set up to compare the shear box, using various types of commercial and milled ice, with the results of similar published experiments and with various types of shear vanes, similar to those used in soils testing. A comparison with shear vanes will be done to see if a shear vane can give a repeatable and meaningful result, because a shear vane would be much easier to use in a field situation where power for instrumentation is difficult to obtain.

TITLE

Model Surface Coating to Achieve Specified Ice Friction Factor (493)

INVESTIGATOR

C. R. Martinson and J. C. Tatinclaux

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	14	0.2	0

OBJECTIVES

In most cases, ice friction is an important component of the forces exerted on a structure subjected to ice action. In the past, a time consuming trial-and-error procedure had to be followed to obtain a specific value of the friction factor. The objective of the research was to develop a method of coating the surface of any physical model used in ice-structure interaction modeling to achieve a specified ice friction coefficient.

APPROACH

The approach followed in this study was to mix a silica powder in the paint used for coating the model. Several concentrations (S) of silica powder (0, 10, 20 and 30% by weight) were tested on specially prepared friction boards. The ice friction factor (f_i) was found to increase with S from 0.07 to 0.14, at a velocity V = 12 cm/s.

ACCOMPLISHMENTS

The friction coefficient, f_i, is defined by: $T = f_i N + T_0$, where T is the tangential load between ice and treated surface measured for the normal load, N, applied on the ice sample. In the present series of experiments the friction factor was found to be an increasing parabolic function of silica powder content, S, expressed in percent by weight, but to vary with the relative velocity, V, between the ice sample and the painted surface. Regression analysis of the test results gave the following equations:

for V = 12 cm/s $\quad f_i = 0.0705 + 0.000083\ S^2 \quad (r = 0.975)$

for V = 1 cm/s $\quad f_i = 0.1066 + 0.000251\ S^2 \quad (r = 0.974)$

where r is the regression coefficient.

These results are tentative and valid only for the test conditions, in particular the type of paint (Chemglaze) and the additive (silica powder) used. However, if they are found to be repeatable, any specified friction factor could be achieved without trial-and-error by adding to the paint the proper amount of this silica powder, thereby saving significant time in the preparation of model structures, whether floating or fixed, to be tested in ice.

TITLE

Measurement of the Shear Strength of Columnar Ice (494)

INVESTIGATOR

D. S. Sodhi and S. L. Borland

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	10	0.2	0

OBJECTIVES

The measurement of the shear strength of ice is often needed for the computation of forces that lead to its shear failure. The objective of this work was to construct a device to accomplish this.

APPROACH

A shear-test fixture, similar to the one used for measurement of the shear strength of composite materials, was fabricated to measure the shear strength of freshwater columnar ice. The objective was to obtain consistent results by testing a large number of precision-machined samples under controlled conditions. The shear strength parallel to the axes of the columnar crystals will be determined with the help of this fixture.

ACCOMPLISHMENTS

The shear-test fixture and fixtures to prepare precision-machined ice samples were fabricated, and methods to machine the samples were established. Several samples were prepared and tested in the fixture, using the Tinius Olsen machine to monitor the load as the sample was loaded. Eight samples were tested and their strength values were in the range of 0.3 to 0.7 MPa, which is well within the range of values (0.2 to 5 MPa) listed in the literature. However, the failure plane was not confined to the desired area. Direct observation of the fixture during testing revealed excessive deformation of the movable portion of the fixture as the ice sample was loaded. To improve the fixture, additional stiffeners have been designed and are to be fabricated by the machine shop when the necessary parts arrive.

TITLE

Water Transport in Frozen Manchester Silt (490)

INVESTIGATOR

Y. Nakano and A. R. Tice

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	22	0.4	0

OBJECTIVES

The objective of this study was to determine the rate of water movement in frozen Manchester silt under isothermal conditions and compare the hydraulic properties of Manchester silt with those of Morin clay.

APPROACH

The experimental method devised by Nakano and Tice was used to determine the mobility of water in frozen Manchester silt under isothermal conditions.

ACCOMPLISHMENTS

Although the mobility of water is greater in Manchester silt than Morin clay under unfrozen conditions, the mobility of water in frozen Manchester silt decreased sharply with the decreasing temperature and became negligibly small at –1.00°C. This sharp decrease of the mobility was caused by the sharp decrease of unfrozen water content with the decreasing temperature in the frozen Manchester silt. We have confirmed that the isothermal mobility of water in frozen soils is closely correlated with the unfrozen water content.

An important question arises whether or not the mobility of water due to temperature gradients in frozen soils is also closely correlated with the unfrozen water content.

TITLE

Effective Modulus of Sea Ice (496)

INVESTIGATOR

J. A. Richter-Menge

RESOURCES

		In-House	Contract
FY	K$	Man-years	K$
88	12	0.2	0

OBJECTIVES

The objective of this project is to synthesize available data at CRREL on the modulus of sea ice. This information will be useful in enhancing the predictive capabilities of analytical and numerical models that can forecast the engineering behavior of ice sheets.

APPROACH

In this investigation we will collect all of the available CRREL test data and examine the effect of salinity, temperature, porosity, structure, sample orientation, strain rate, degree of confinement, etc., on the modulus of the ice. Once the analysis has been completed, the results will be compared to earlier work by other investigators. In addition, we will evaluate current constitutive models that are used to predict the modulus of ice. We anticipate that this evaluation will indicate that the models will have to be modified to give correct results. Unfortunately, most of the data published to date were obtained on testing machines that were not stiff enough and did not have closed-loop control to produce a known, constant strain rate. Modification of the models, however, is beyond the scope of this study.

ACCOMPLISHMENTS

Data from over 700 mechanical property tests completed at CRREL on a variety of saline ice types were compiled and transformed into a consistent computer language and format. Collectively, this data set provides state-of-the-art information on the behavior of saline ice in uniaxial compression and tension and at confined compression at strain rates varying from 10^{-2} to $10^{-5}s^{-1}$ and temperatures from –20 to –3°C. These data are now being used to determine the variables (ice type, porosity, temperature, loading rate, and loading state) that significantly influence the effective Young's modulus of saline ice. Initial analysis shows that there is a very consistent relationship between modulus and porosity over a wide range of ice types. Once our final analysis is complete, we will derive empirical equations that quantitatively relate the modulus to the ice properties of influence. These models will be useful in the evaluation and prediction of large scale ice deformation problems.

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CRREL's In-House Laboratory Independent Research (ILIR) Program provides a means for innovative high-risk basic research. This report briefly describes the 17 ILIR research projects undertaken in FY88. Work in this program addressed various problems concerning the physical properties of ice, snow and frozen ground; remote sensing of lake and river ice; water content of frozen or partially frozen materials; and physical/mathematical models for experimental or predictive use in ice research.

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